Gas Laws

Kinetic Molecular Theory

Kinetic Molecular Theory

Explains the properties of matter in terms of the energy of the particles and the forces that act between them.

Based on 3 assumptions:

1. Matter is composed of very small particles called <u>molecules</u>.

2. Molecules are in <u>constant motion</u>.

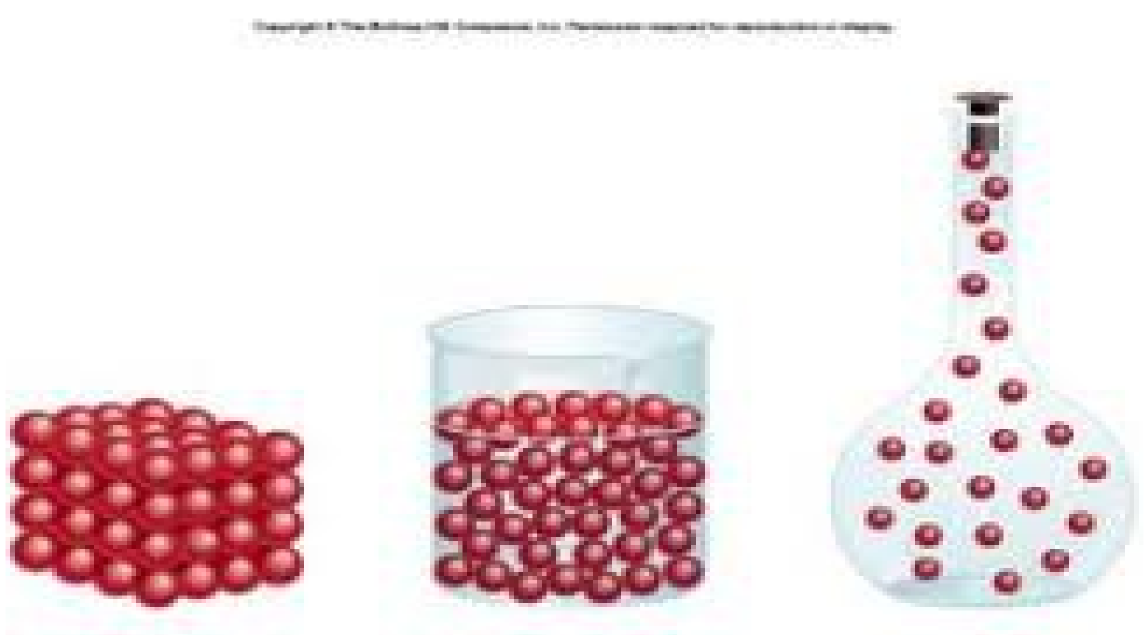
Continued

3. When the molecules collide with each other or the walls of a container, there is no loss of energy.

Elastic collision- collision where no energy is lost or gained.

Solids/Liquids/Gases

Describe the molecules in the following images.



Assumptions continued

**Ideal Gas- an imaginary gas that perfectly fits all the assumption of the KMT

2 more assumptions…

4. There are no forces of attraction or repulsion between gas particles.

5. The average kinetic energy of gas particles depends on the temperature of the gas.

   Temperature- measure to the average kinetic energy of particles

Temperature

- Measure of the average kinetic energy
- Kinetic Energy = $1/2\ mv^2$
- Units: Fahrenheit (°F), Celsius (°C), and Kelvin (K)
- Kelvin (K): directly relates temperature to kinetic energy
- Absolute Zero: 0K, temperature where motion stops

Converting temperature

Celsius to Kelvin

$$T_{Kelvin} = T_{Celsius} + 273$$

Kelvin to Celsius

$$T_{Celsius} = T_{Kelvin} - 273$$

Practice

Convert the following temperatures to Kelvin or Celsius.

1. 15°C

2. 100 K

3. 125°C

4. 0 K

5. 722 K

6. –100°C

Pressure

Pressure- force per unit of area

Gas pressure- the force exerted upon a container by a gas; caused by gas particles striking the sides of the container.

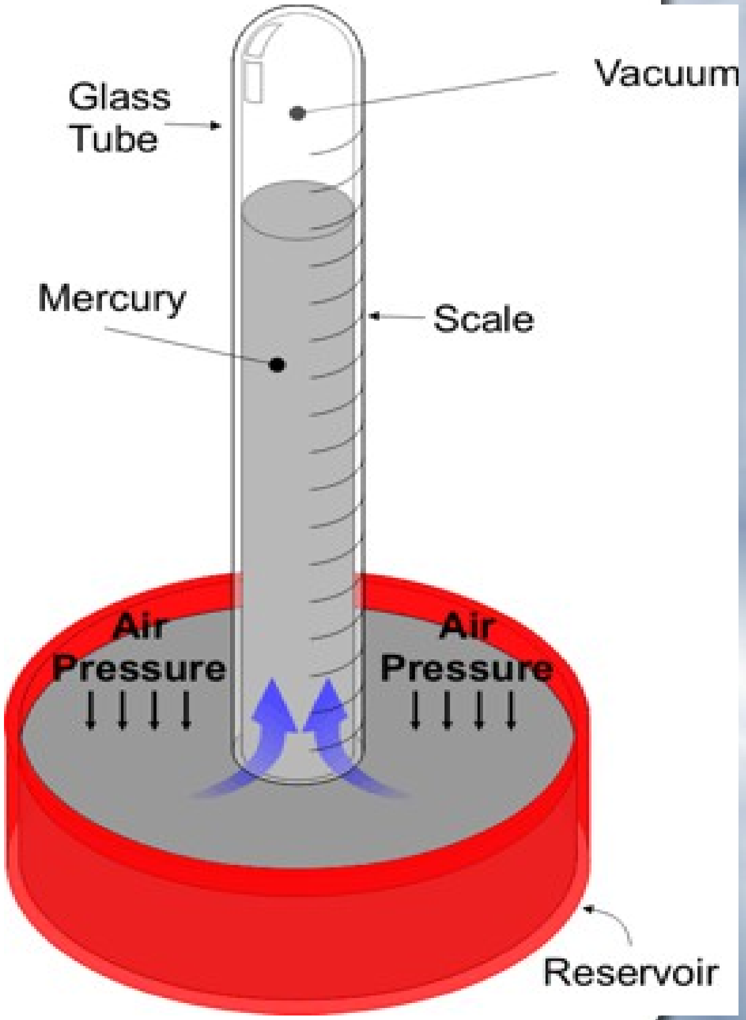
Continued

Pressure can be measured in several different units.

The standard atmosphere (atm) is

defined using the barometer

*** 1 atm= 760 mm Hg = 760 torr**



Pascal- SI unit for measuring pressure

1 atm= 101300 Pa = 101.3 Kpa

Standard Temperature and Pressure

*Standard set of experimental conditions used to make comparison of data easier.

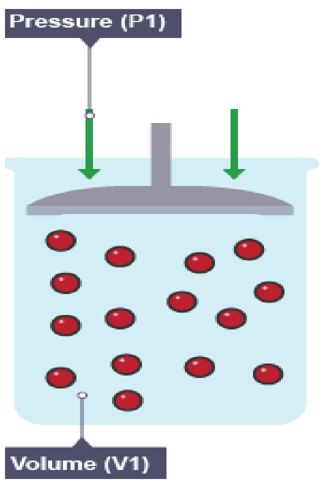
At STP:

T= 0°C and P= 1 atmosphere

Think Pair Share-PreAP

In your notebook answer the following questions regarding the model below on your own.

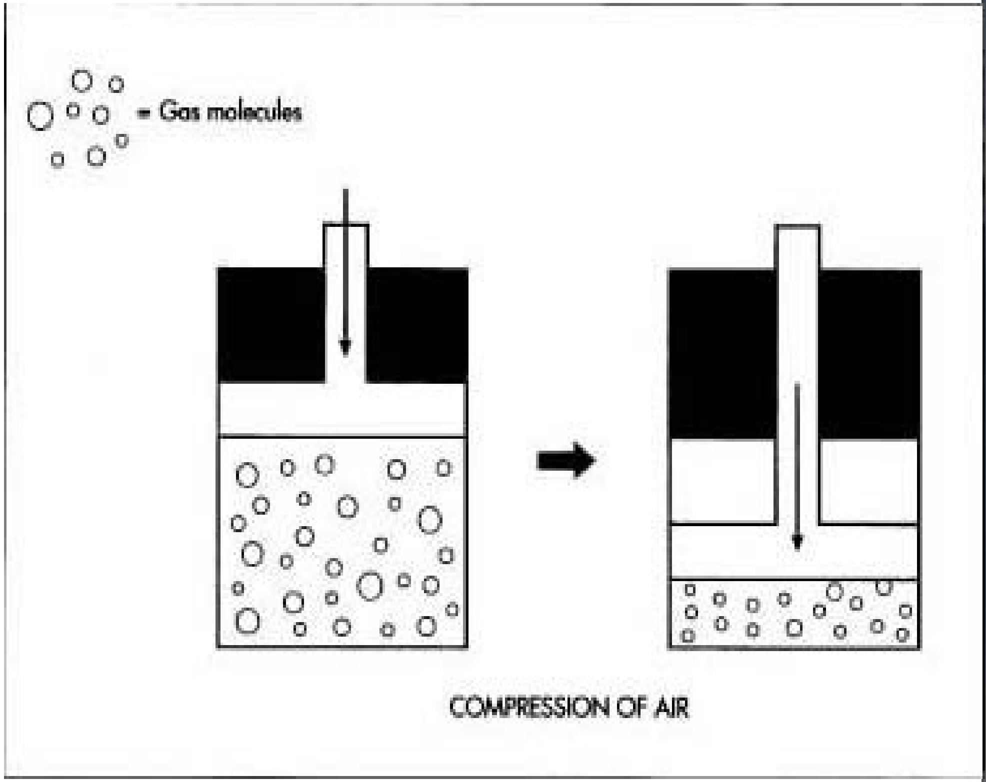
1. What happens to the space between the particles of a substance when the pressure on the container is increased and the volume is kept constant? How does this affect the volume?
2. What happens to the spaces between the particles when the temperature increases and the pressure is kept constant? How does this affect the volume?
3. When the temperature of the sample is increased:
   A. What happens to the force with which the particles strike the side of the container?
   B. What happens to the frequency of collisions with the side of the container
   C. How does this affect the pressure of the sample?



Behavior of Gases

1. *Gases can* ***expand***

2. *Gases can be* ***compressed***



** Expansion and compression are affected by <u>temperature</u> and <u>pressure</u>.

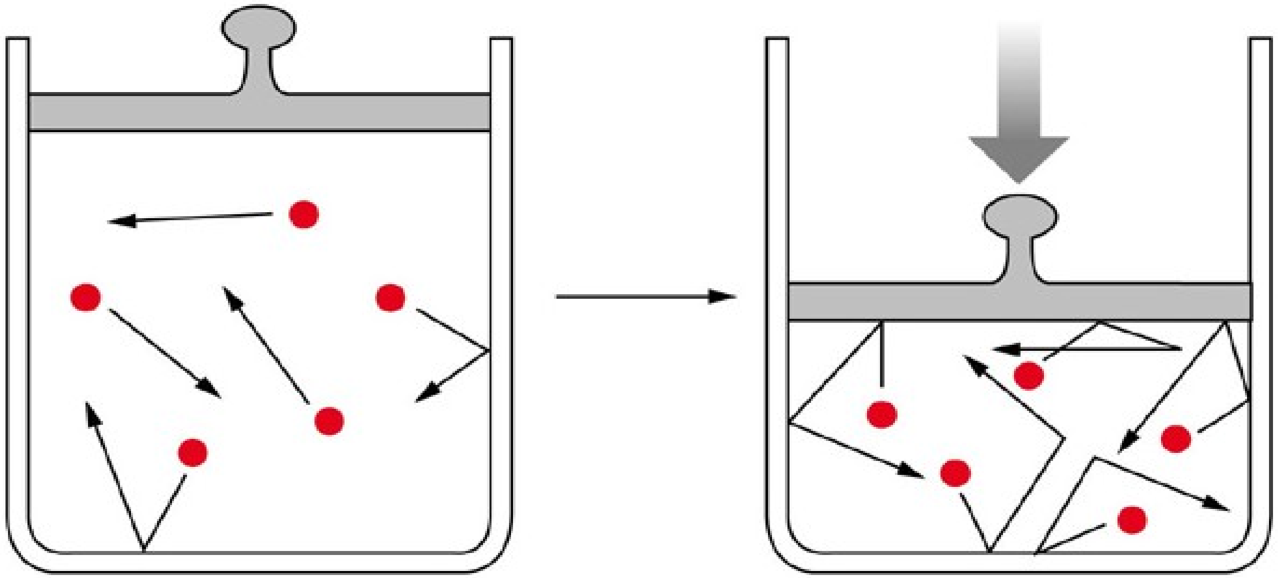
Gas Laws

Gas laws express the behaviors of gases as mathematical relationships.

Boyle's Law

-Relates pressure and volume

-States that the pressure and volume of a gas are inversely proportional to each other at constant temperature.



Boyle's Law

Formula:

$$P_1 \cdot V_1 = P_2 \cdot V_2$$

P_1= initial Pressure

P_2= final pressure

V_1= initial volume

V_2= final volume

Example #1

At constant temperature, a balloon with a volume of 25mL is at a pressure of 2.5 atm.   When the pressure is decreased to 1.0 atm, what will the new volume be?

Charles' Law

-Relates volume and temperature

-States that the volume of a gas is directly proportional to the temperature of the gas at constant pressure

Charles' Law

Formula:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

V_1= initial volume

V_2= final volume

T_1= initial temperature

T_2= final temperature

**Temperature must be in Kelvin!

Example #2

If a sample of gas has a volume of 2.0L at room temperature, 25°C, what will be the new volume if the temperature increased to 30°C?

Gay-Lussac's Law

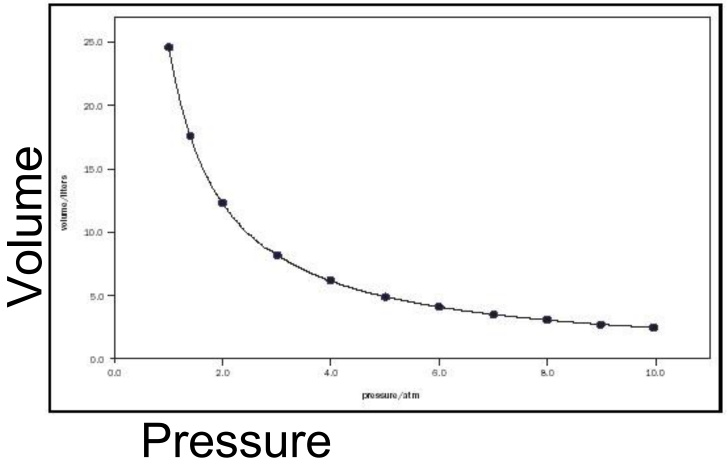
-Relates pressure and temperature

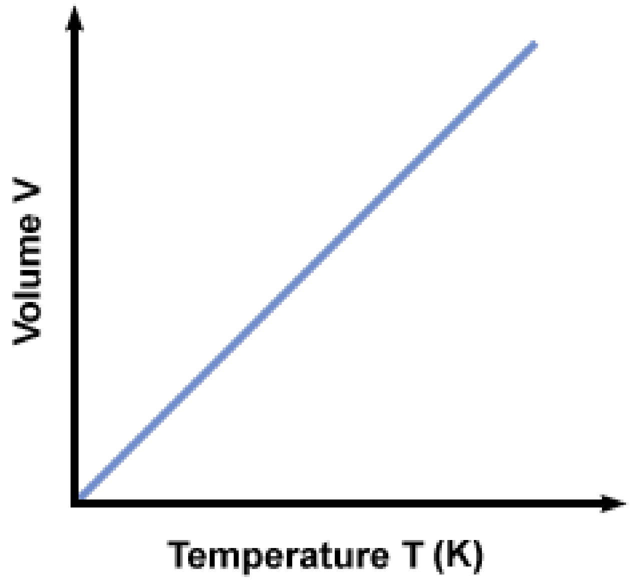
-States that the pressure of a gas is directly proportional to the Kelvin temperature of the gas at constant volume

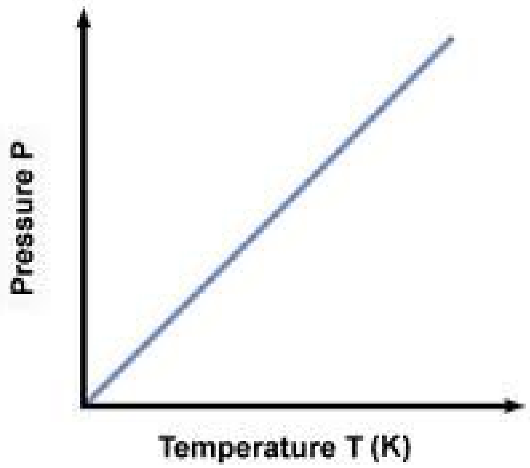
Formula:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Label the graphs according to the law it represents:





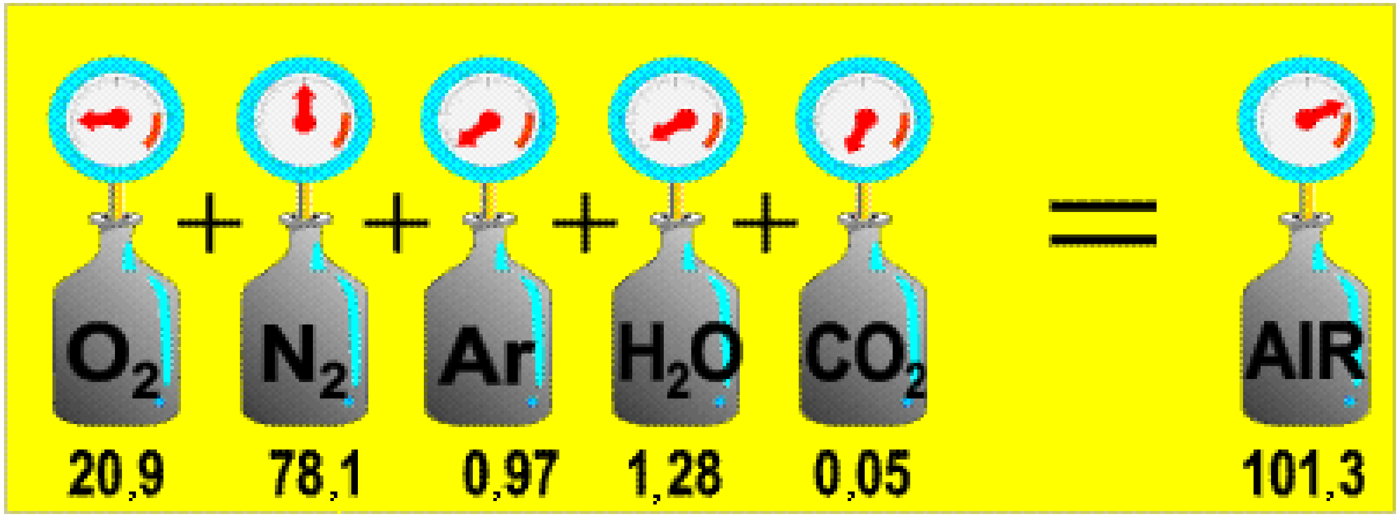


PreAP only

Dalton's Law of Partial Pressures

-states that the pressure of a gas **<u>mixture</u>** is the sum of the **partial pressures** of the individual components of the gas mixture.

Formula: $P_{total} = P_1 + P_2 + P_3 + \ldots$



Example #3

A vessel contains nitrogen, hydrogen, & oxgyen. If the partial pressure of nitrogen is 2.5 atm, the partial pressure of hydrogen is 0.75 atm, and the partial pressure of oxygen is 1.25, what is the total pressure?

Example#4 (Partial Pressure)

A mixture of oxygen, hydrogen and nitrogen gases exerts a total pressure of 278 kPa. If the partial pressures of the oxygen and the hydrogen are 112 kPa and 101 kPa respectively, what would be the partial pressure exerted by the nitrogen?

Dalton's Law & Mole Fraction

$$P_A = \chi_A P_{Total}$$

P_A = partial pressure of component A

χ_A = mole fraction of componenet A

P_{Total} = total pressure of system

<u>Mole fraction (χ_A):</u> ratio of moles of individual to total moles present

$$\chi_A = \frac{n_A}{n_{total}}$$

n_A = moles of A

n_{total} = total moles in sample

PreAP Example #4 (Partial Pressure)

A reaction vessel contains 3 moles of CO_2, 4 moles of O_2, and 2 moles of N_2, and has a total pressure of 800mmHg. What is the partial pressure of each component?

Ideal Gas Law

-Relates pressure, volume, temperature and number of <u>moles</u>.

Formula: $PV = nRT$

P= pressure

R= universal gas constant

V= volume

T= temperature in Kelvin

n= moles

Universal Gas Constant (R)

-value can vary depending on pressure units being used.

$$R = \text{ideal gas constant} = 0.0821 \frac{L \cdot atm}{mol \cdot K} = 8.31 \frac{L \cdot kPa}{mol \cdot K} = 62.4 \frac{L \cdot mmHg}{mol \cdot K}$$

Volume is in liters

Temperature is in Kelvin

Example #5 (Ideal Gas Law)

What is the pressure of 5 moles of a gas at 30°C in a 2 liter container?

Example #6 (Ideal Gas Law)

A 250mL of a gas exerts a pressure of 760 torr at 10°C. How many moles of gas are present?

Avogadro’s Law

Avogadro’s principle state that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.

**1 mole of gas = 22.4 L at standard temperature and pressure.

Example #7

Calculate the volume that .881 mol of gas at standard temperature and pressure will occupy.

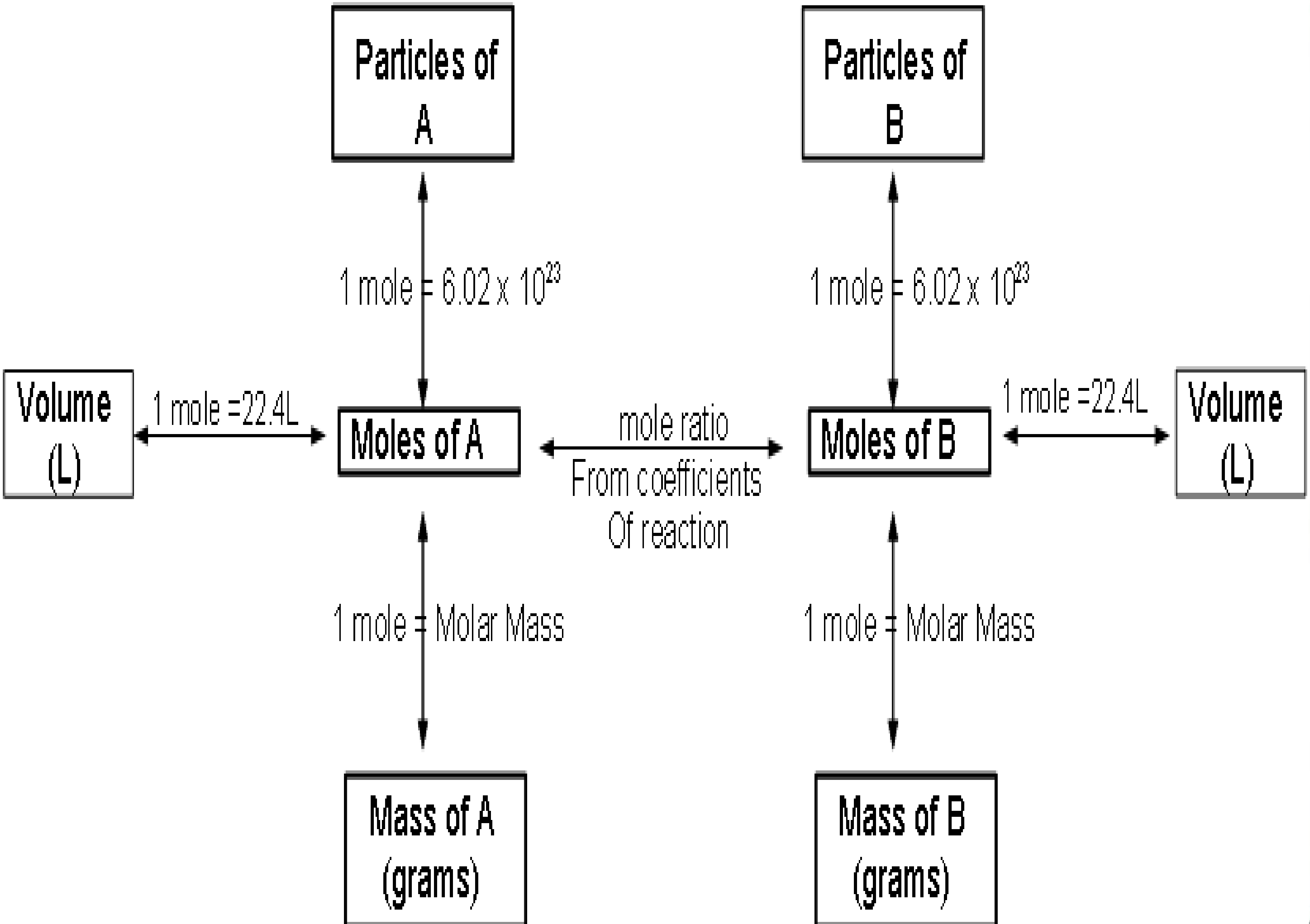
Gas Stoichiometry- @STP

Avogadro's Law allows us to say:

@STP 1 mole of gas has a volume of 22.4L

1 mole = 22.4L   @STP

** We can now add to our stoichiometry mole map!


Particles of A
Particles of B
1 mole = 6.02 x 10^23
1 mole = 6.02 x 10^23
Volume (L)
1 mole =22.4L
Moles of A
mole ratio
From coefficients
Of reaction
Moles of B
1 mole =22.4L
Volume (L)
1 mole = Molar Mass
1 mole = Molar Mass
Mass of A (grams)
Mass of B (grams)

Example # 8

If 4.75 moles of water vapor decomposes at STP , what volume of O_2 will be produced?

$$2H_2O(g) \rightarrow 2H_2(g) + O_2(g)$$

4.75 moleH_2O	1 mole O_2	22.4L
1	2moleH_2O	1 mole O_2

= 53.2L O_2

Gas Stoichiometry- Not at STP

$$2\ Cl_{2(g)} + C_2H_{2(g)} \rightarrow C_2H_2Cl_{4(l)}$$

What volume of Cl_2 will be needed to make 75.0 grams of $C_2H_2Cl_4$ at 24°C and 773 mm Hg?

Gas Stoichiometry- Not at STP

$2\ C_8H_{18(l)} + 25\ O_{2(g)} \rightarrow 16\ CO_{2(g)} + 18\ H_2O_{(g)}$

How many grams of water would be produced if 20.0 liters of O_2 gas were burned at a temperature of -10.0°C and a pressure of 1.3 atm?